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ON THE CRUSHING RESPONSE OF FOAM CORE SANDWICH SPECIMENS SUBJECTED TO EDGEWISE COMPRESSION WITH VARIED SIZE CIRCULAR FACE/CORE DEBOND: EXPERIMENTAL

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Abstract

Foam core sandwich structure and used extensively in the primary structures of aircraft and launch vehicles. The study presents the result of an experimental investigation on failure analysis of foam core sandwich panels with varied size circular debonds. Edgewise compression test is conducted to characterize peak load carrying capacity in a variety of sandwich specimens (60mm×60mm) which contain circular debonds of 0.5-inch, 1-inch, 1.5-inch and the 2.0-inch diameter between the Glass/Epoxy Face sheet and Foam Core. Launch industry criteria were used in selecting the Debond sizes. PTFE inserts of required size are used to obtain the desired debonded area between the face sheets and the core. Specimens containing 0.5-inch, 1.0-inch, 1.5-inch, and 2.0 inch debonds were tested according to ASTM C 364-99. Testing demonstrated that reduction in strength is less for 0.5inch to 1.5inch debonds and 2.0-inch debond exhibits significant strength reductions. The study showed that a multiple failures occurs with face sheet buckling motivating delamination in the specimen, eventually leading to face sheet compression failure for debonds larger than 1.5 inches. The circular debonds of 1.5 inches set the thrush hold for the debonding failure of the panels considered.

KEYWORDS: Sandwich construction, Edgewise compression & Debonding

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Original Article

INTRODUCTION

Sandwich composites are extensively used in structural applications as the building material which gives high strength to weight ratio and good bending properties. They are used in the manufacture of ships, aircraft and other automotive components. The debonding between the core and the facing sheet is a matter of concern as this damage reduces the strength and load carrying capacity of the sandwich panels. Debonding in a sandwich panel can occur due to various factors like manufacturing defect while employing different techniques for manufacturing or an impact during the service or maintenance. The knowledge of the load carrying capacity reduction due to the different size of debonds is an essential criterion for the assessment of the sandwich panels. The compressive properties, collapse modes and crushing characteristics of various types of composite sandwich panels in a series of edgewise compression tests can be determined [1]. In-plane direction sandwich panels can be compressed and initial failure modes can be identified as face sheet failure, global and local buckling [2]. Fatigue behavior and damage tolerance of foam core sandwich structures with composite faces is an essential aspect that needs to be addressed [3]. Debonding can occurs in a sandwich panel due to the presence of geometric imperfections in the core-facesheet interfaces [4]. The sensitivity analysis performed proves that the core must be thick enough to

prevent buckling, which is low density polyethylene foam-based sandwich panels built by rotational molding is a progressive phenomenon, conducted an experimental investigation which uses a simply supported flat panels loaded in edgewise compression and as strips loaded in flat-wise flexure under two concentrated loads to determine the behavior of sandwich constructions having facings of both equal and unequal thickness on cores of expanded-type honeycomb construction [5]. The material properties of the constituents (facings, adhesive, core), geometric dimensions and type of loading depends on various failure modes in composite sandwich beams [6]. Behavior and failure of Three- and four-point bending of composite sandwich beams with debonds were performed and quantified [7]. The tension, compression, flexure and shear behavior with a variation of panel thickness, through-thickness fiber configuration, and density, and other parameters on panels were discussed [8]. The Different Core Material analyses for a light-weight sandwich panel for trailers. Strength calculations and precise applications solution can be made by selection of different materials in manufacturing the sandwich structure [9] [10].

EXPERIMENTAL PROCEDURE

Material Selection and Specimen Fabrication

The core material Divinycell closed-cell 'H' grade foam core was selected for this study with a density of 80 kg/m^3 and 10 mm thickness. This foam core an ideal selection because of its lightweight, superior fatigue and impact resistance, damage tolerance, and excellent cost-effectiveness. Face sheets were fabricated using 10 mils thick 320 GSM of open plain woven from glass fabric cloth. The foam core was sandwiched between two layers of woven glass fabric on each side. A synthetic fluoropolymer of tetrafluoroethylene named Polytetrafluoroethylene (PTFE) was used throughout the study for debonding the core and the face sheets. The debonding was done using the PTFE inserts on both the sides of the specimen**.** PTFE has a very low coefficient of friction and debonds can be fabricated in the sandwich specimens by the PTFE inserts of the required size and desired debonded area between the face sheets and the core. Due to its low friction, in industrial uses, PTFE is used for applications where sliding action of parts is essential like gears, slide plates, plain bearings. Circular debonds of various sizes are used throughout the study. Due to its highly anti-adhesive properties, PTFE inserts are used in our work to create circular debonds between the face sheet and the core surfaces. PTFE specimens containing 0.5 inch, 1.0 inch, 1.5 inch, and 2.0 inch diameter debonds were fabricated and tested. Debond sizes were selected based on typical criteria used in the launch industry. The fabrications of the sandwich panels were done using the vacuum infusion process. The Araldite GY257 resin and ARADUR 2963 hardener are used for the preparation of sandwich panel and have good micro-cracking resistance, adhesive properties, mechanical properties fatigue resistance, and less degradation from water corrosion. The resin and hardener were mixed according to the mixing ratio of resin and hardener 10:4.5by weight.

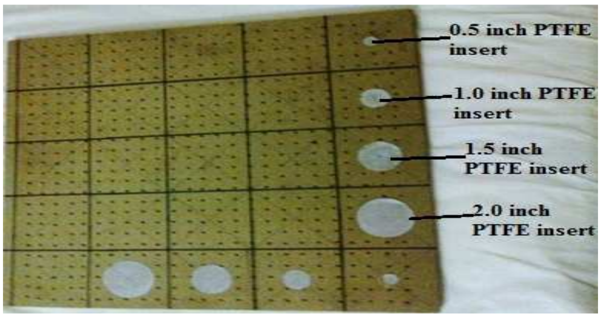

Figure 1: Core with PTFE Inserts of Different Size Placed on the Surface of the Foam core

Edgewise Compression with Varied Size Circular Face/Core Debonds

Edgewise compression test was conducted using ASTM C 364-99 to characterize peak load carrying capacity in a variety of sandwich specimens (60mm×60mm) which contains without debonding circular debonds of 0.5-inch, 1 inch, 1.5inch and the 2.0-inch diameter between the Glass/Epoxy Face sheet and Foam Core. The test was conducted in a universal testing machine (TUE-C-400).

Figure 2: The Universal Testing Machine TUE-C-400

Figure 3: The specimen at the Start of the Edgewise Compression Test

Figure 4: Specimens with Different Sized Debonds
i) No Debond,
ii) 0.5 inch Debond,
iii) 1.0 inch Debond,
iv) 1.5 inch Debond and,
v) 2 inch Debonds.

RESULTS AND DISCUSSIONS

Edgewise compression test was conducted for the square sandwich panels of side 60mm and plotted using a computer controlled Data acquisition system attached to the Universal testing machine. The Load-displacement plots were obtained for specimens having differently sized debonds i) No debonds, ii) 0.5 inch debond, iii) 1.0 inch debond, iv) 1.5 inch debond and v) 2 inch debond. 5 mm/min crosshead speed was applied to all the specimens.

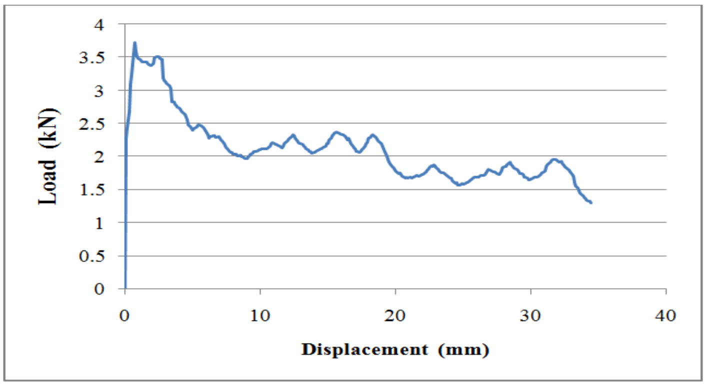

Figure 5: Load-Displacement Plot of the Sandwich Specimen with No Debonds

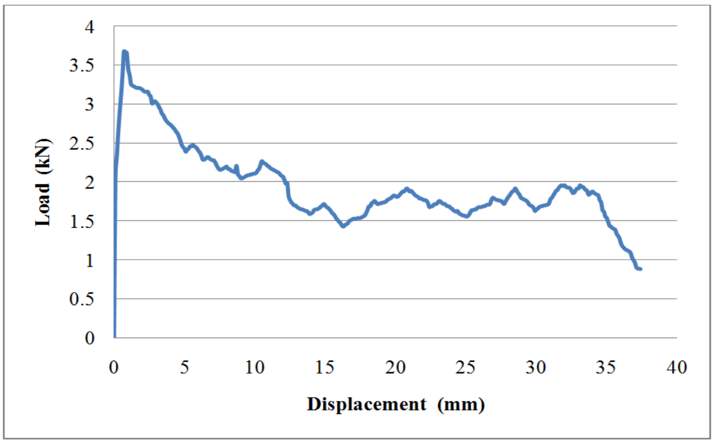

Figure 6: Load - Displacement Plot of the Sandwich Specimen with 0.5-Inch Diameter PTFE Insert

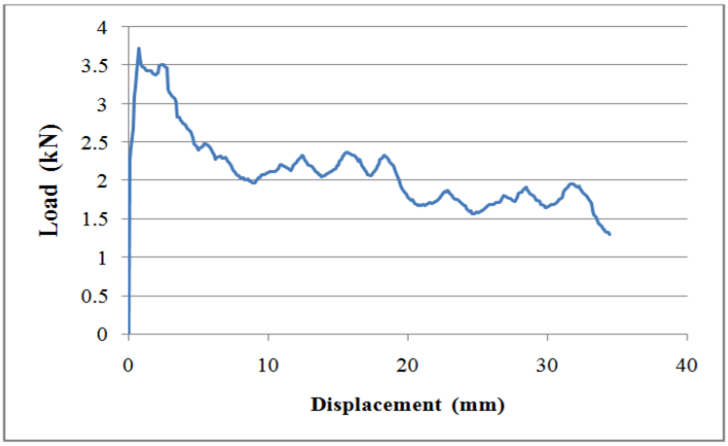

Figure 7: Load-Displacement Plot of the Sandwich Specimen with 1.0 Inch Diameter PTFE Insert

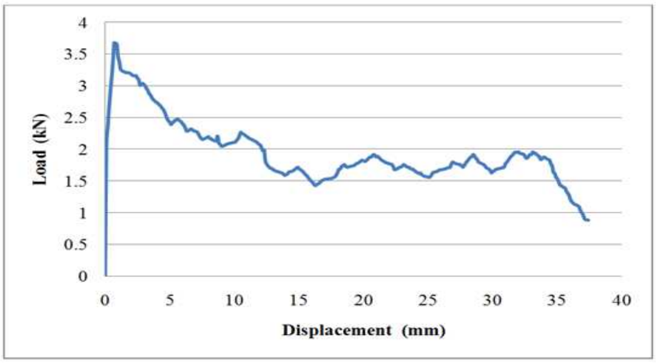

Figure 8: Load-Displacement Plot of the Sandwich Specimen with 1.5 Inch Diameter PTFE Insert

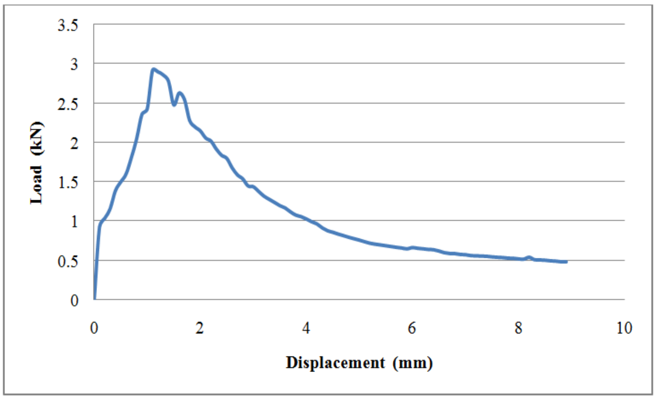

Figure 9: Load-Displacement Plot of the Sandwich Specimen with 2 Inch Diameter PTFE Insert

Figure 10: Specimens after Face Sheet Buckling when Subjected to Compression

Table1: Tabulation Showing the Compressive Young's Modulus and the Reduction in Strength of the Composite Sandwich Structure with Increasing Size of Debond

Debond Diameter (inch)	Peak load (kN)	Compressive Strength (N/mm^2)	Compressive Young's Modulus (kN/mm^2)	Reduction in Peak Load (%)
0	3.72	5.486	0.239	-
0.5	3.68	5.427	0.228	1.075
1.0	3.64	5.368	0.199	2.151
1.5	3.60	5.301	0.195	3.226
2.0	2.92	4.306	0.062	21.505

CONCLUSIONS

Varying diameter inserts of 0.5-inch, 1.0-inch, 1.5-inch, and-2.0 inch were subjected to edgewise compression test method as preferred to appraise fully bonded sample and specimens with debonds. The 0.5-inch, 1.0-inch, and 1.5-inch diameter debond showed face sheet compression failure as the typical failure mode. The 2.0 inch debond demonstrated significant strength reductions. The reduction in the Strength is less for 0.5 inch to 1.5 inch only up to 3.226%. For 2-inch debonds, the strength reduction is large 21.505%. The experiment on the crushing response of foam core sandwich specimens subjected to edgewise compression with varied size circular face/core debond proves that for debonds larger than 1.5-inch, results in significant step by step delamination propagation and leading to face sheet compression with face sheet buckling failure. The debond diameter of 1.5-inch is the critical value above which the peak load carrying capacity of the sandwich specimen reduced drastically. The critical value can be noteworthy during a routine maintenance check using Non-destructive techniques or during the manufacturing process of sandwich composites.

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